A TREATISE, &c.

CHAPTER I.

ON THE STEAM ENGINE.

MY aim in the following pages is to give as clear and concise an account as possible of the application of the power of steam, and other artificial agents to the moving of vessels upon the water, being one of those great improvements which the arts have derived from the cultivation of the sciences, within little more than the last half century. The vast importance of navigation, particularly to an insular and commercial nation, like Great Britain, is too obvious to need comment, and any substantial improvement that tends to diminish the risk and uncertainty of this art, cannot but be hailed with the most unequivocal approbation; and such is the application of steam to the purposes of navigating vessels. During a long series of years, the motion of vessels upon the surface of water has depended almost entirely upon the action of the wind upon their sails, or the application of manual labour to oars. The last of these operations is the most ancient, but is nevertheless the most certain, since the uncertainty of the wind is proverbial, while, on the contrary, if we have sufficient strength, the oar will take a vessel in any direction, even in opposition to both wind and current. The improvements that late years have produced in the forms of vessels, in the construction and application of sails and rigging, and in the manner of using them, have in no small degree removed the uncertainty of sailing; but cases still remain, and must for ever continue to do so, in which motion cannot be produced in this way, because no vessel can ever be constructed to sail in direct opposition to the wind, and when it altogether abates and an entire calm succeeds, the moving power is wholly suspended. In such cases nothing but the oar remains, and although this is always available in small craft, and may even be occasionally used to advantage for towing large vessels, yet the motion so produced is uniformly very *slow*, and is only obtained at a great expense of labour. Oars were formerly used with success in the galleys of the ancients, and are even yet retained for large vessels among some of the eastern nations, particularly in the Mediterranean sea. In these cases the rowers are seated at a very trifling height above the water, and are so numerous as to constitute the chief burthen of the vessel, consequently but little stowage room is left for the transport of merchandize, and from the room required by the men, the occupation in which they are constantly engaged, and the incumbrance of their oars, such vessels are much less fit for the purposes of war than the service of the merchant. The totally different form of British ships, with their sides highly elevated above the water, to enable them to ride in all seas, entirely precludes the use of oars, independent of which their room is required for more important purposes, and hence the wind (notwithstanding its uncertainty) has alone been resorted to for moving all large vessels, although it has in numberless instances produced the most dreadful disappointments, not only by delaying mercantile expeditions when their sailing has been of the utmost importance, but has defeated the most skilful and scientific manœuvres of our ablest and most experienced naval commanders, by the power upon which they depended for motion being suddenly suspended, or from changes of the force and direction of the wind taking place which could not be contemplated.

However useful and valuable the power of wind may be when it is blowing temperately in the right direction, still it must be confessed that if rowing, or any other artificial means of producing motion, could be uniformly maintained without that great expence and waste of room and labour which always accompanies it, it must be a great desideratum; and it will be shown, as I proceed, that all the several applications of steam and other artificial powers to the purposes of navigation approximate more or less to the operation of rowing.

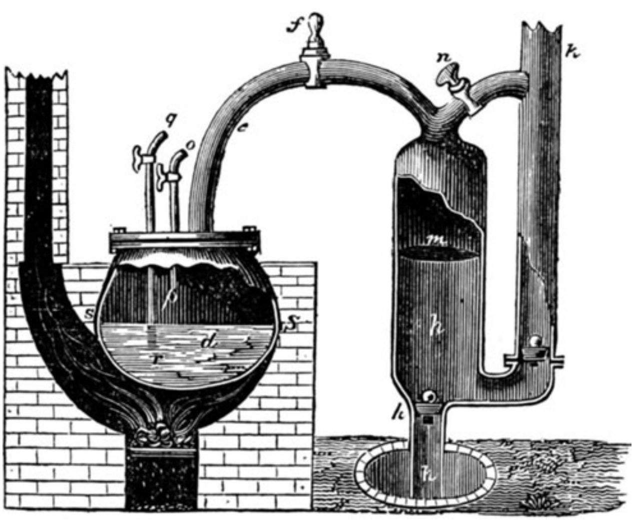
The application of the power of steam to the general purposes of navigation is so recent, and as yet is so little understood by those concerned in maritime affairs, as to plead a forcible excuse for the production of the present work; and for the same reason I feel that it would be by no means complete if I were not to preface it with such a general account of the nature of steam, and of the engines or machines in which it is employed, as will enable any one unacquainted with their construction to judge for themselves of their respective merits, and to form a just estimate of the truth and certainty of the truly philosophical principles upon which they act.

The great expansive force of steam, or that particular vapour that arises from the boiling of water and other fluids, has been long known to be so great as to bid defiance to the strength of every vessel in which it has been attempted to be confined: and upon this principle and the circumstance of steam being reconvertible into water again with astonishing rapidity whenever it is cooled, does the power of the steam engine depend. Water, in common with most other fluids, is subject to slow and spontaneous evaporation into the air at ordinary temperatures, and whenever it is so carried off, it must be previously formed into a vapour, which from the slowness of the process is invisible. But if the heat of the water is increased, the effect becomes visible and sensible, and at 212° of Fahrenheit's thermometer (which is the common boiling point of water in the open air at its mean pressure) the steam produced becomes equal in power to the pressure of the atmosphere, and hence the evaporation proceeds rapidly and is palpably visible. At this temperature, the steam of water occupies about 1800 times the bulk of the water in a cold state, or in other words, a single cubic inch of water, when made to boil, will produce 1800 cubic inches of steam, having a degree of elastic force equal to the air of the atmosphere, which at an average exerts a pressure of 15 lbs. upon every square inch of surface. Hence, if these 1800 cubic inches of steam are received or retained in a vessel having but 900 cubic inches of capacity, the contained steam will be compressed into half its natural bulk, and it will exert a force of twice the power of the atmosphere, or 30 lbs. upon the inch; and if the vessel had a capacity of only 450 inches, then the steam would exert a power of 60 lbs. on the inch to burst open the vessel, and so on in proportion to the condensation that takes place. The power producible by confining steam and increasing its heat may therefore be increased, perhaps without limit, and yet notwithstanding this great force, the instant the steam is cooled down again below the boiling point it is completely annihilated, for the steam then re-collapses into its state of water, and of course shrinks into its original small bulk.

The first person who, it appears, thought of applying this valuable principle of the great dilutation of water by heat, and its re-condensation by cold, to the purpose of obtaining a motive power, was Edward Somerset, Marquis of Worcester, a nobleman of great mechanical acquirements, who lived in the reign of King Charles the Second, and to him the invention of the steam engine is therefore universally ascribed. The marquis did not, however, describe how the machine was to be formed or constructed, but merely published a small tract in 1663, called

"*A Century of the names and scantlings of such inventions as he had tried and perfected,*" and in which it stands as the sixty-eighth of his hundred contrivances, many of which appear so marvellous that it has been doubted whether they ever were invented or not, though this is in some measure set at rest by several of them having since been carried into effect. The first person, however, that produced an effective steam engine, on principles nearly accordant to those described by the marquis, was Capt. Thomas Savary, who, in 1698, obtained a patent for his invention, and tried it before the Royal Society of London in the following year, and as this engine affords an excellent example of the manner in which steam acts to produce power, I shall be the more particular in my description of the principles of this machine, which will elucidate what is to follow.

FIG. 1.



The annexed diagram, Fig. 1. copied from Professor Millington's Epitome of Natural Philosophy, in which a very copious account of the rise and progress of the Steam Engine through its various stages of improvement is given, is not a correct representation of the engine as constructed by Capt. Savary, but is on this account, the better suited to my present purpose, because it is divested of all those appendages which would make the machine appear complex and intricate. The steam is produced in a metal boiler *d*, which is fixed in a furnace of brickwork, with a chimney of sufficient height to cause the fire to burn briskly under the boiler, for the purpose of converting the water with which the boiler is about half filled, into steam. The boiler has a close top, or plate of metal screwed over it, so as to prevent the escape of any of the steam thus formed, except by the pipe *e*, in some part of which there is a cock *f*, by the opening or shutting of which, the steam can be confined within the boiler, or permitted to escape at pleasure. The further end of the pipe *e* communicates with the upper part of a strong hollow metal cylinder *p*, from the bottom of which proceed two pipes. The pipe marked *h*, proceeds down into the well or other situation, from which the water is to be raised, and the other turns upwards as at *k*, to convey that water to the elevated position to which it may be required to be forced. Each of these pipes are closed by strong conical valves, opening upwards as at *i* and *k*, in such manner that any water that gets above these valves cannot descend again; and *n* is a cock fixed in a short pipe, which forms a communication between the inside of the rising pipe *k*, and that of the cylindrical vessel *p*. Now after what has been said of the nature of steam, it will be obvious, that if the cock *f* is shut, while the water in the close vessel *d* is boiling, that an accumulation of highly elastic and powerful steam will soon take place in the upper part of that vessel, and which would burst open that vessel with great violence, if the process was long continued. And likewise that if the cock *f* should be opened while the steam was so accumulated, it would instantly rush through the pipe *e*, and fill the cylinder *p*, and the pipe *k* with steam, which by its heat and force would expel the atmospheric air previously contained in the cylinder, and drive it up the pipe *k*. The cocks *n* and *f*, being now shut, would leave the cylinder *p* filled with steam; and if cold water was now thrown upon the outside of that cylinder, or any other means resorted to for cooling it, the steam within it would be condensed, or be reconverted into water, which would occupy so little space at the bottom of the cylinder, compared to the steam lately within it, that its inside would be left nearly in a state of vacuum, and as the cock *n* is shut, and the valves both open upwards, no external air could get into that vacuous space by either of these openings, but the pressure of the atmosphere upon the surface of the water in the well, would drive that water up the pipe *h*, and into the hollow space *h*, as high as the letter *m*, or to a greater or less height, in proportion to the perfection of the vacuum produced, and provided the extreme height of the vessel *p*, did not exceed 33 feet above the surface of the water to be raised; and as the water so raised could not return back again through the valve *k*, of course the vessel *p* would remain nearly filled with water. As the cock *f* is kept shut during the whole time that the water is so rising, this allows time for the steam to accumulate again, and therefore, upon opening the cock *f* a second time, the steam will again rush to the cylinder *p*, which is nearly pre-occupied by water, and the elastic force of the steam, will therefore be exerted upon the surface of the water at *m*, and provided it be greater than the gravitating force of the column of water in the rising pipe *k*, it will drive the whole of the water contained in *p*, through the valve, and up the pipe *k*, so that the vessel *p*, will once more be filled with steam, which done, the cock *f* must be again shut, and the cock *n* opened for an instant, so as to let a momentary jet of cold water run from the pipe *k* into, or even on to the outside of the cylinder *p*, by which the steam will be instantly condensed, and a vacuum formed, which will be supplied with water from the well again, and thus, by keeping up the elastic force of the steam by a good fire, and alternately opening the cocks at *f* and *n*, may any quantity of water be raised at pleasure.

The height to which the water can be raised, must depend upon the force of the steam, and the strength of the materials of which the boiler and cylinder are formed. If they are sufficiently strong, steam of any required power may be obtained, by increasing the fire; and since the steam of water boiling at 212°, is just a balance to the pressure of the atmosphere, so if that force be doubled, or made twice as strong as the atmospheric pressure, it will exert a force equal to 30 lbs. upon every superficial inch of the boiler that contains it, or will have that tendency to burst it, and will at the same time, sustain a column of water 33 feet high, in any rising pipe as *k*, in the Figure. In thus stating the amount of pressure within the boiler at 30 lbs. upon every superficial inch, it must be understood that the sensible or actual pressure exerted, only appears equal to 15 lbs. upon the inch, because the external air of the atmosphere presses upon the boiler with a force of 15 lbs. on each inch, tending to crush it inwards, and consequently, this 15 lbs. of external pressure, must in every case be subtracted from whatever power the steam may be exerting within the boiler; and following this rule, it is found that when the steam within the boiler so exerts an actual force of 15 lbs. it will sustain and balance a column of water in the rising pipe *k*, of 33 feet in height. But the gravitating force of fluids is simply as their heights, consequently, to raise the column of water twice as high, or to 66 feet, the steam must be twice as strong, or equal to a pressure of 30 lbs. on the inch; to raise it three times as high, or 99 feet, the steam must be equal to 45 lbs. on the square inch, and so on in like proportion for greater or less heights.

In the actual construction of this engine, Capt Savary used two recepients like *p* for the water, in order to save time, because one was filling while the other was discharging its contents; he likewise adopted two boilers of different dimensions, the one being used to produce steam, while the other was kept constantly filled by a part of the water raised, and which was kept in a nearly boiling state by the same fire, and so arranged, that whenever the water of the steam boiler was nearly exhausted by evaporation, it was replenished on opening a cock, the compressed steam being used to force a sufficient quantity of the heated water into the steam boiler. Among other useful and ingenious contrivances which Capt. Savary introduced into his engine, may be noticed *the trial cocks*, for ascertaining that the steam boiler contained its proper quantity of water. As all boilers are opake, it would be impossible, without a contrivance of this kind, to know when they were properly filled; and this is quite necessary to the steady and uniform action of the machine, because if a boiler is too full, there may not be space enough left above the water to contain the steam as it is produced; and on the contrary, if the water should be nearly or quite exhausted, the steam might be produced so rapidly, as to become dangerous and unmanageable, or the lower part of the boiler might be melted, or burnt and destroyed. The trial cocks of the boiler are therefore so useful, that they have been retained through all the various improvements of the steam engine, and are shown at the letters *o p q* and *r* in Fig. 1. They consist of two small cocks of the common kind, screwed into the upper ends of two tubes of different lengths, which are so fixed into the top of the boiler, that the longest tube *r*, may project about 3 inches below what should be the general average surface of the water within the boiler, when properly filled, as indicated by the line *S S* in the figure. The shorter pipe *p*, fixed to the other cock, terminates below, at about 3 inches above the average water surface; consequently, whenever the cock *q* is opened, while the boiler is at work, the force of the steam ought to drive water up its pipe and discharge it, while the other cock *o* ought to discharge steam without water. Should the boiler at any time contain too much water, so as to cover the bottoms of both the pipes, then boiling water will be discharged by both cocks; and on the contrary, whenever the water is so far diminished, as to be below the ends of both the pipes, they will discharge steam only without water; consequently, by an occasional opening of these two cocks, the surface of the water may be regulated to within 3 inches above or below its proper height, as effectually as if it was at all times visible.

Many engines on Savary's construction, were erected in different parts of England, for supplying houses with water, draining fens, and other purposes; among which, is that of pumping water from ships, which Savary alludes to in a work he printed in 1702, entitled, the *Miner's Friend*, being a full description of his machine, and a recommendation of it to such as were engaged in raising water from deep mines; to which purpose it was applied in several instances, although attended with a great consumption of fuel, and considerable danger, arising from the very powerful steam that became necessary, whenever the water was to be raised from very great depths. Capt. Savary also first used the term, *horse power*, as a standard of comparison between what his engines did, and the number of horses required to produce the same effect.

It would be beyond the limits or intention of the present work, to enter into an historical detail of all the progressive steps which the steam engine has gone through, and I shall therefore confine myself to a brief account of its grand epochs of improvement. On this account, I shall pass over the researches of Doctor Papin, in France, and others in this country, with the mere notice, that that most valuable and important appendage to every steam boiler, *The Safety Valve*, originated with Doctor Papin, who also contrived the *two-way*, or as it is very generally, though improperly, called the *four-way-cock*, for distributing the steam alternately to the top and bottom of the steam cylinder, for the purposes, and in the manner which will hereafter be described.

The safety valve is a metal valve, usually of the conical form, opening